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STUDY INTO THE OPERATIONAL CHARACTERISTICS OF A RECOILLESS RIFLE MOUNTED ON ARMY HELICOPTERS. VOLUME I. EXPERIMENTAL INVESTIGATION INTO THE EFFECT OF SUPPRESSING RECOILLESS RIFLE BACK BLAST UTILIZING A POROUS DIFFUSER AND DEFLECTIONS

Sheldon D. Smith

Lockheed Missiles and Space Company, Incorporated

Prepared for:

Watervliet Arsenal

July 1974

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This study was concerned with developing a method or device reduce blast overpressure of a 105 mm recoiless rifle to permit its mounting on the outboard bomb shackle of a Cobra helicopter. The overpressure emanating from the breech nozzle observed from previous firings of the 105 mm recoilless rifle would produce excessive loads on the helicopter resulting in structural damage. Hardware modification of the Cobra/105 weapon system had to be restricted to the weapon, i.e., the structure of the (Continued)

helicopter could not be strengthened in the blast region. Considering the constraints imposed on the weapons system, the objective of the study could be translated into the specific requirement of reducing the peak overpressure experienced by the helicopter structure to a maximum level of 5 psi overpressure. One of the experimental firings made during this contract produced a pressure field for which no pressures were measured which exceeded 5 psig. This result, as well as other experimental results, indicate that it is at least feasible to mount a modified 105 mm recoilless rifle on a helicopter which would not produce overpressures on the helicopter which are above 5 psig.

Lockheed's experimental approach to solving the overpressure problem was to design and fabricate two devices which were to be mounted at the nozzle breech of the 105 mm recoilless rifle test weapon. The first and primary device built was a cylindrical porous wall shroud for which the porosity could be varied. The second device consisted of a pair of parallel flat plates. The devices were installed on the test weapon and fired on several occasions during the period of February-July 1973 at Picatinny Arsenal. The experimental results for numerous firings are contained in the report.

The flow field generated by a recoilless rifle firing presents a complex time dependent mixed flow problem involving the interaction of two gases with strong shocks. Because of the transient nature of the flow field, a method was developed using a time-dependent finite difference technique to numerically solve the unsteady inviscid adiabatic flow equations. The computer code developed was applied to the 105 mm flow field and comparisons were made with experimental data.

Also included in the report is a development of a dense gas equilibrium thermochemical analysis program which can be used to predict the post combustion products of high chamber pressure combustion such as occurs in recoilless rifles and other armament. An inviscid flowfield analysis of the 105 mm exhaust plume is also described.

WVT-CR-74022

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STUDY INTO THE OPERATIONAL CHARACTERISTICS OF A RECOILLESS RIFLE MOUNTED ON ARMY-HELICOPTERS

FINAL REPORT

VOLUME I

EXPERIMENTAL INVESTIGATION INTO THE EFFECT OF SUPPRESSING RECOILLESS RIFLE BACK BLAST UTILIZING A POROUS DIFFUSER AND DEFLECTIONS

SHELDON D. SMITH

U.S. ARMY ARMAMENT COMMAND

PREPARED FOR

BENET WEAPONS LABORATORY
WATERVLIET ARSENAL
WATERVLIET, N.Y. 12189

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LOCKHEED MISSILES & SPACE COMPANY, INC.
HUNTSVILLE RESEARCH & ENGINEERING CENTER
HUNTSVILLE RESEARCH PARK
4800 BRADFORD DRIVE, HUNTSVILLE, ALABAMA

Study into the Operational Characteristics of a Recoilless Rifle Mounted on Army Helicopters

Final Report

Volume I

Experimental Investigation into the Effect of Suppressing Recoilless Rifle Back Blast Utilizing a Porous Diffuser and Deflections

October 1973

Contract DAAF07-73-C-0151

Prepared for Commanding General, Watervliet Arsenal
Watervliet, New York 12189

by

Sheldon D. Smith

APPROVED: John W. Benefield
John W. Benefield, Supervisor
Fluid Mechanics Section

J. S. Farrior
J. S. Farrior
Resident Director

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FOREWORD

This document presents the results of work performed by the Fluid Mechanics Section of the Lockheed-Huntsville Research & Engineering Center. This report is Volume I of a two-volume final report, as required to fulfill Contract DAAF-07-73-C-0151. The results presented in this volume represent the experimental portion of the investigation into the feasibility of mounting a 105 mm recoilless rifle on Army helicopters. The work was performed for the Army Weapons Command (WECOM), Watervliet Arsenal, Watervliet, New York, under the direction of Mr. Don L. Spring, Mr. Charles A. Andrade and Major John R. Adams, III.

This document constitutes Volume I of a two-part final report. The other volume, printed separately, is:

Volume II – "Analysis of the Flow Field Generated During the Firing of a Recoilless Rifle."

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Section 1
INTRODUCTION AND SUMMARY

Lockheed Missiles & Space Company, Huntsville Research & Engineering Center conducted a study entitled "Study into Operational Characteristics of Recoilless Rifles Mounted on Army Helicopters," Contract DAAF-07-73-C-0151, for the Army Weapons Command (WECOM) Watervliet Arsenal, Watervliet, N. Y.

The study was concerned with developing a method or device to reduce blast overpressure of a 105 mm recoilless rifle to permit its mounting on the outboard bomb shackle of a Cobra helicopter. The overpressure emanating from the breech nozzle observed from previous firings of the 105 mm recoilless rifle would produce excessive loads on the helicopter resulting in structural damage. Hardware modification of the Cobra/105 weapon system had to be restricted to the weapon, i.e., the structure of the helicopter could not be strengthened in the blast region. Considering the constraints imposed on the weapons system, the objective of the study could be translated into the specific requirement of reducing the peak overpressure experienced by the helicopter structure to a maximum level of a 5 psi overpressure. One of the experimental firings made during this contract produced a pressure field for which no pressures were measured which exceeded 5 psig. This result, as well as other experimental results, indicate that it is at least feasible to mount a modified 105 mm recoilless rifle on a helicopter which would not produce overpressures on the helicopter which are above 5 psig.

A dominant controlling process in blast wave attenuation has been determined experimentally and the experimental trends have been qualitatively verified analytically (Volume II). Ultimate recoilless operation with a shroud can be obtained and optimized through tailoring the shroud and breech nozzle using such techniques as a diverging shroud, angled porous shroud holes or nozzle design. Specific applications would involve tailoring a rifle system by combining chamber pressure time history, grain design and diffuser design to obtain a particular weapon systems performance.

The study was comprised of two parts, an experimental investigation and an analytical study. The purpose of this document is to present the results of the experimental study.

Lockheed's experimental approach to solving the overpressure problem was to design and fabricate two devices which were to be mounted at the nozzle breech of the 105 mm recoilless rifle test weapon at Picatinny Arsenal, N. J. The first and primary device built was a cylindrical porous wall shroud for which the porosity could be varied. The second device consisted of a pair of parallel flat plates. The devices were installed on the test weapon and fired on several occasions during the period of February-July 1973 at Picatinny. The experimental data which were obtained was pressure data from transducers which were mounted on a ground reflection plane flat pallet (to simulate the carrier profile) located 48 inches from the nozzle centerline and parallel to the centerline. The transducers were located at several stations down the pallet. Pressure data were also taken utilizing free field static pressure "pencil gauges." However, the data which are discussed in this report are for the flush mounted pallet gauges as they most closely measure the overpressures which might be experienced by the helicopter structure.

Section 2
DISCUSSION

2.1 BACKGROUND

Before a solution to the 105 mm recoilless rifle back blast overpressure problem was undertaken, the first step was to understand what were the controlling processes in the flow field and resulting overpressures. It was stated in the RFP for this contract, that the overpressure seemed to be caused by the initial shock front and possibly by quasi-steady jet plume impingement. Lockheed undertook a study under a separate contract, reported in Ref. 1 which showed that for an 81 mm recoilless rifle there would not be plume impingement on a flat plate located 60 inches from the breech nozzle centerline. Appendix B of Vol. II of this report describes a similar analysis which was performed for the 105 mm recoilless rifle. Figure 1 shows the inviscid plume boundaries which are obtained for maximum chamber pressures of 6350 and 12000 psia. It is apparent from this figure that the steady state inviscid free plume will not intersect a plane located 48 inches from the nozzle centerline. Based on these results it appears that the overpressures which are present are due to the initial shock front.

Once the problem appeared to be defined, methods were looked at which might at least alleviate part of the overpressures. Nozzle contouring and area ratio changes to lower the nozzle exit pressure were dismissed because the main effect of changing the nozzle would be to reduce the exit pressure and the plume boundary maximum diameter. Since there seemed to be no direct plume impingement, reducing the plume boundary probably would not significantly affect the overpressures.

The solution to the problem then seemed to be reduced to devising a method of reducing or "directionalizing" the initial shock wave. Conversations between Lockheed-Huntsville personnel and Lockheed Propulsion Company personnel have indicated that at least part of the overpressures could be reduced

1. Ring, L. R., and S. D. Smith, Recoilless Rifle Plume Definition Study," LMSC-HREC D306136, Lockheed Missiles and Space Co., Huntsville, Ala., August 1972.

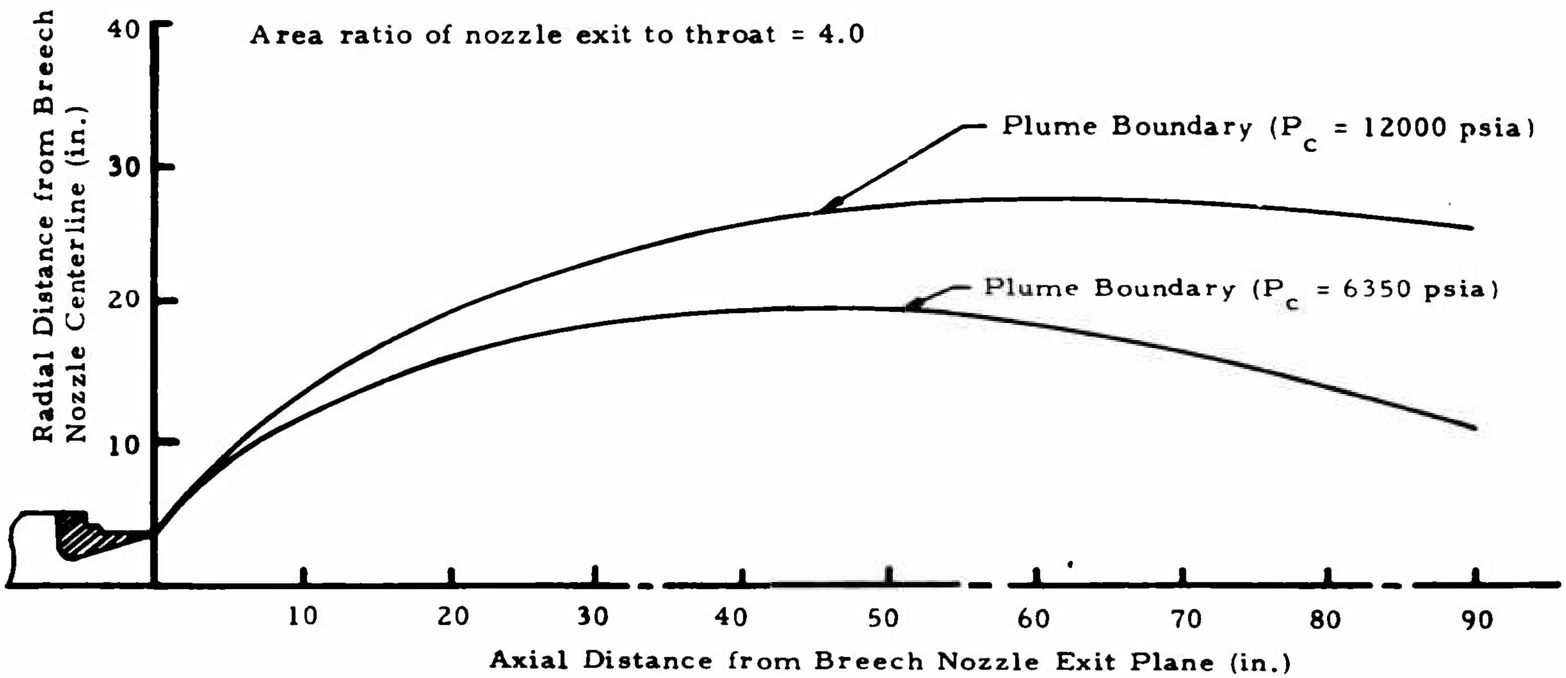


Fig. 1 - 105 mm Recoilless Rifle Inviscid Exhaust Plume Boundary as a Function of Peak Chamber Pressure

through grain design and pressure-time history tailoring. However, this approach was not investigated further because solutions involving internal ballistics were not included in the scope of this particular study. Two devices were proposed which were thought to show some promise of providing a solution to the back blast overpressure problem. The first and primary device was a porous wall cylindrical shroud that fitted over the end of the breech nozzle and extended aft from the rifle. The method by which this device could reduce overpressures was by reducing the strength of the shock front by diffusing some of the mass out the sides of the shroud and by directionalizing the shock by means of the tube itself. Directionalizing the shock would elongate the shock front so that by the time the shock front reached the helicopter structure the entire shock front would be spread over a larger area and thus the strength of the shock at any one point would be lower.

The second device investigated was a pair of parallel flat plates that fit over the breech nozzle and extend aft of the rifle. It was theorized that by orienting the plates parallel to the helicopter surface, the shock front would be directionalized up and away from the surface. By orienting the plated perpendicular to the reflection plane it could also be determined how the helicopter rotor would be affected by the blast.

The shroud and flat plate devices were to be tested utilizing the Watervliet test rifle and pallet setup of Fig. 1b (Enclosure (A) of the letter dated 4 December 1972 from J. A. Pisarri to the contractors). These devices were to be fired by Picatinny Arsenal personnel in New Jersey under the guidance of Watervliet and Lockheed personnel. Further details of the shroud and deflector designs and test setup are discussed in Sections 2.2 and 2.3.

2.2 SHROUD/DIFFUSER AND DEFLECTOR DESIGN AND FABRICATION

The design of porous wall shroud and flat plate deflector was undertaken with four items controlling the overall design: (1) ensure that both devices remain on gun during the firing; (2) both devices should be able to use same mounting hardware; (3) devices should not come apart due to pressure forces imposed during firing; and (4) designs of both devices should be such that more than one parameter may be examined with each device. A sketch of the basic 105 mm test weapon is shown in Fig. 2a and a sketch of the two devices on the weapon is shown in Fig. 2b.

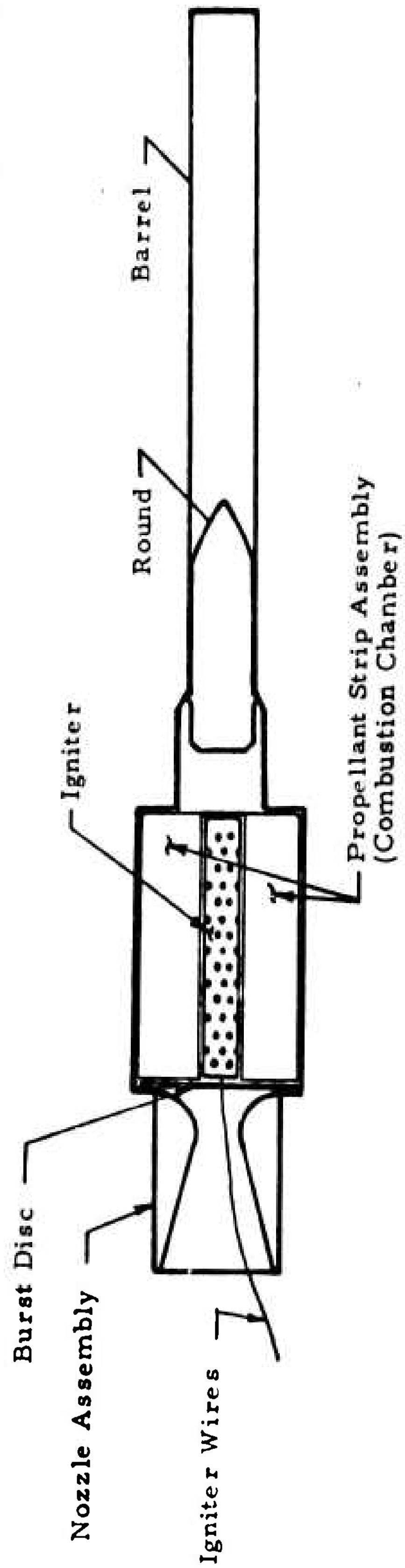
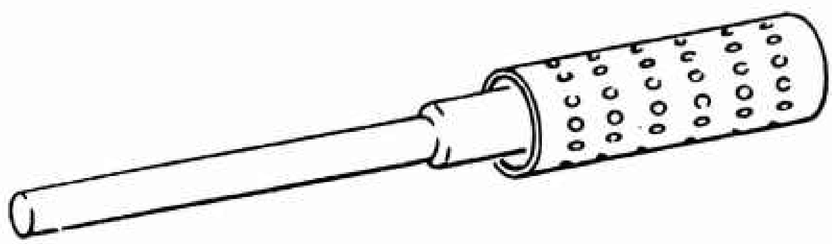
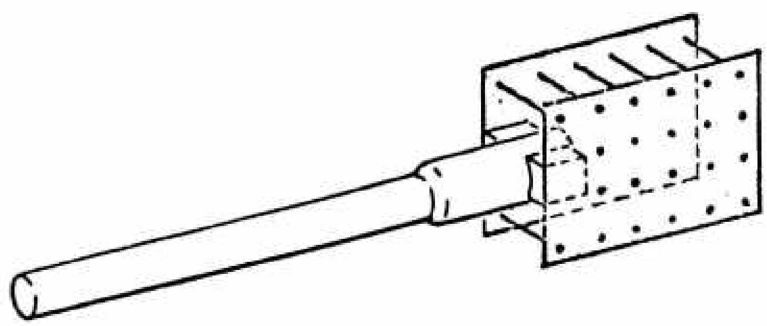


Fig. 2a - Sketch of 105 mm Recoilless Rifle Test Weapon



Porous Shroud Device



Parallel Plate-Deflector Device

Fig. 2b - Variable Porosity and Flat Plate Devices

The final design of the porous wall shroud consisted of two 1/4-inch steel tubes, the inner tube having an ID of 10 inches and the outer tube having an ID of 10-1/2 inches. Each tube had 705 1-inch holes end-milled through the walls. All the holes would line up, giving approximately 35% porosity. The design was such that the outer shroud would rotate about the inner shroud while the shroud was attached to the test weapon. The shroud was attached to the test weapon by means of a collar which mated to the shroud and four 1-inch threaded rods which were connected to a pair of fittings which in turn were connected to the lip on the plenum chamber housing. This attach mechanism is a redesign of the original as the shroud came off the rifle on the first firing. Figure 3 is a photo of the installation. Variable porosity was obtained by scribing index marks on the inner cylinder corresponding to increments of 5% in porosity. The outer shroud was attached to the inner shroud at each of the porosity "settings" by means of a pair of bolts positioned about the cylinders. The shroud extended 48 inches beyond the exit plane of the weapon when it was installed. By sliding the outer shroud out and lining up the holes, length variations were obtained while maintaining a porosity/unit length of 35%.

This was only one problem encountered during fabrication after each shroud was "trued" up and the proper amount milled from the outside surface of the inner shroud. The outer shroud was found to be slightly warped or "banana shaped" which would not allow the inner shroud to rotate 11 degrees with respect to the outer shroud. The problem was solved by machining the inner surface of the outer shroud enough so that the two shrouds would rotate 11 degrees. It would have been easier and cheaper to machine the outer surface of the inner cylinder, but for structural reasons it was necessary to machine the outer cylinder. The holes in both cylinders were cut separately through each cylinder using an "end mill." The "end mill" eliminated the drill centering problem. The two cylinders were not "drilled together because "burrs" created by drilling 705 holes might "weld" the two cylinders together so that they could not be separated.

The parallel flat plate deflector device consisted of a pair of 16 x 31 x 1/4-inch flat steel plates with 2 angle irons welded to the outside surface. The flat

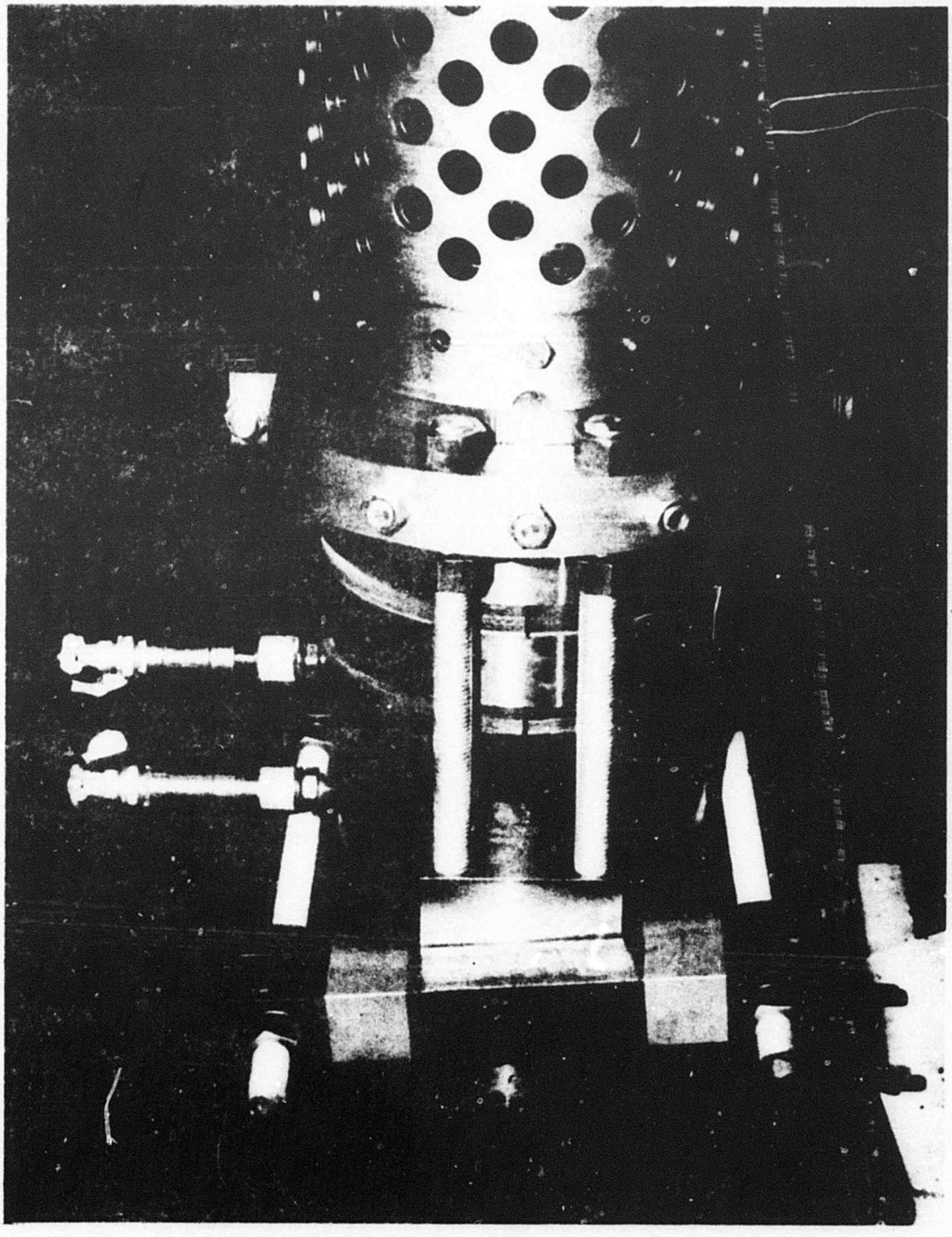


Fig. 3 - Photo of Shroud Installation on 105 mm Recoilless Rifle Test Weapon

plates were held together with 3/8-inch threaded rods and tubular spacers. The plates were 11 inches apart. The deflectors attached to the plenum chamber housing using two V-blocks of metal which fitted around the housing and butted up against the inner surface of each of the flat plates. Four 1 inch threaded rods were used to bolt the two plates and metal brackets together. Installed, the plates extended 20 inches downstream of the exit plane.

The only problem that was anticipated with the flat plate devices was the possibility of the gaseous drag on the threaded attach rods might pull the device off the rifle. This problem was alleviated by using a minimum number of rods and firing a low chamber pressure round. The only visible effect present after firing was the support rod on the nozzle centerline was deformed about 1/4 inch at its center.

Except for the shroud coming off the rifle on the first round both devices were designed, fabricated and mated with the weapon with minimum difficulty.

2.3 EXPERIMENTAL SETUP

The experimental firings of the 105 mm test rifle with the shroud and deflector devices were made at the Picatinny Arsenal test range. The experimental setup which was utilized for these firings is shown in Fig. 4. This setup is the same as was specified by Watervliet as in Fig. 1b (Attachment A of the letter from J. A. Pisarri to all contractors dated 4 December 1972). This setup consists of two free field "pencil" gauges (ARC-LC33) positioned 48 inches from the nozzle centerline at 15 and 30 degrees from the centerline measured from the exit plane. The primary instrumentation which was used to determine the effectiveness of the devices are five flush-mounted transducers (ARC-LC-70) mounted in a 6-inch strip of aluminum located on a plywood pallet 48 inches from the nozzle centerline parallel to the nozzle centerline. These gauges are located 12, 24, 48, 83 and 179 degrees from the nozzle exit plane. Two Baldwin SR-4 transducers were used to measure the chamber pressure in the forward and aft ends of the combustion chamber. The projectile velocity was measured by using a pair of coils and measuring the time it takes the round to travel between the two coils.

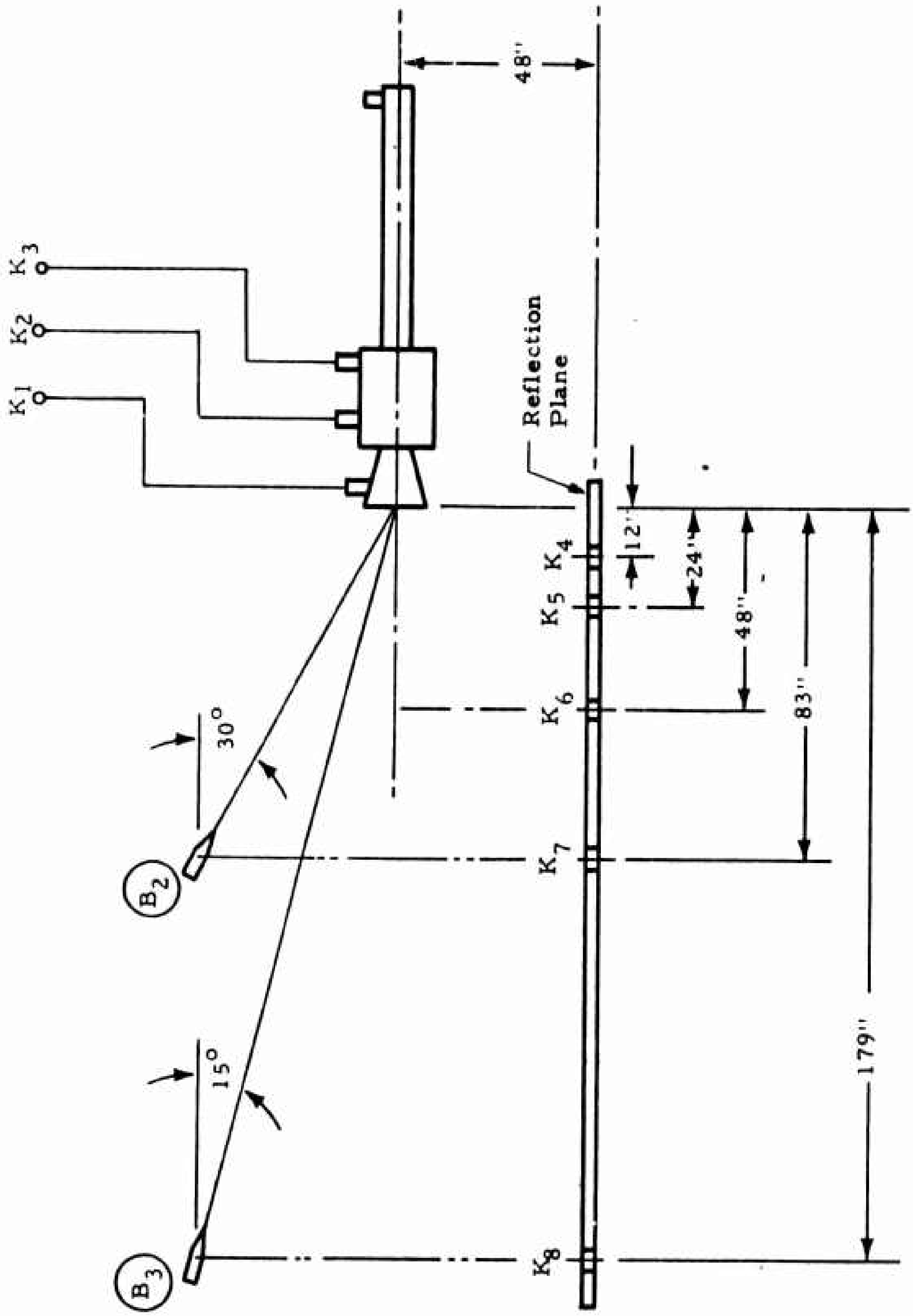


Fig. 4 - SEAS 105 mm Recoilless Rifle Blast Reduction Experiment Setup (Free and Reflected Blast Fields)

The flush-mounted transducers were located at the approximate position of the side of the helicopter fuselage. The purpose of the flush-mounted gauges was to measure the reflected pressures existing at the surface of the pallet. It was hoped that these results would most closely simulate the actual conditions experienced by a helicopter side panel.

The first series of tests including three firings with the shroud were made using the above test setup. The data obtained from the flush-mounted transducers indicated that a peak in the reflected pressures might occur between Station 83 and 179 so that the remainder of the firings were made with the transducers located at 48, 83, 115, 147 and 179 inches from the exit plane. The data obtained with the first test setup also indicated that there might be some "ringing" in the transducer response due to vibrations occurring in the aluminum plate in which the transducers were mounted. Picatinny alleviated this problem by cutting the aluminum strip in several places so that the remainder of the data obtained after May 1973 did not seem to have any of the previous "ringing" frequency in the data.

2.4 DATA REDUCTION

The data obtained from each firing consisted of a strip chart which had a trace for each channel containing instrumentation. Each channel (transducer) was calibrated at the beginning of a day of firing. A typical strip chart with calibration data is shown in Figs. 5 and 6.

A typical trace for a single transducer consists of a straight line up to the time when blast wave crosses the transducer at which time a sharp "spike" occurs in the trace followed by oscillations and at time secondary spikes. The strip chart data was reduced by Picatinny Arsenal personnel and was recorded on a data sheet for each round. The reduced data for each channel are presented in the form of pressure and are presented for each peak on the trace.

The data in this report are presented using two methods of data reduction. The first method is to use the data as reduced by Picatinny and take the first spike in the pressure as the maximum overpressure. (This is true for

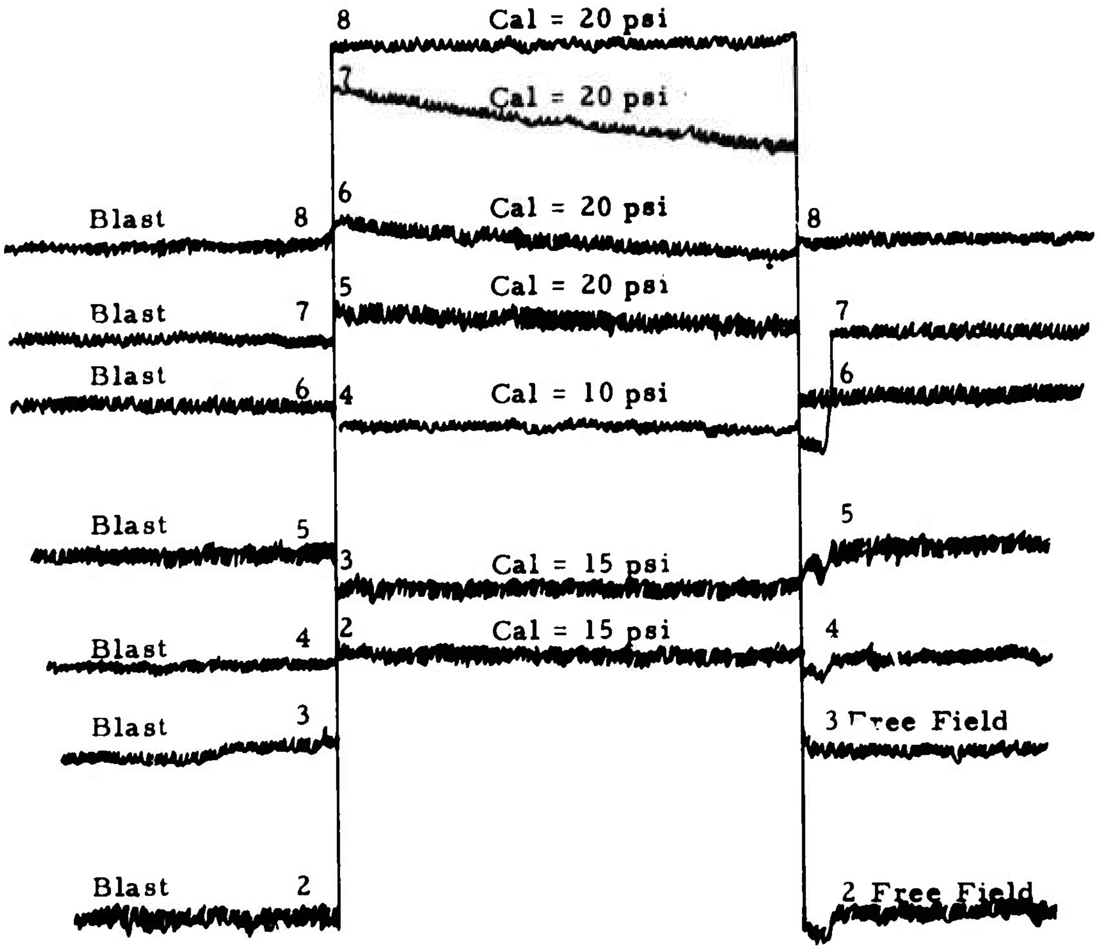


Fig. 5 - Calibration Data Strip Chart for Typical 105 mm SEAS Round (Round 46, 11 June 1973)

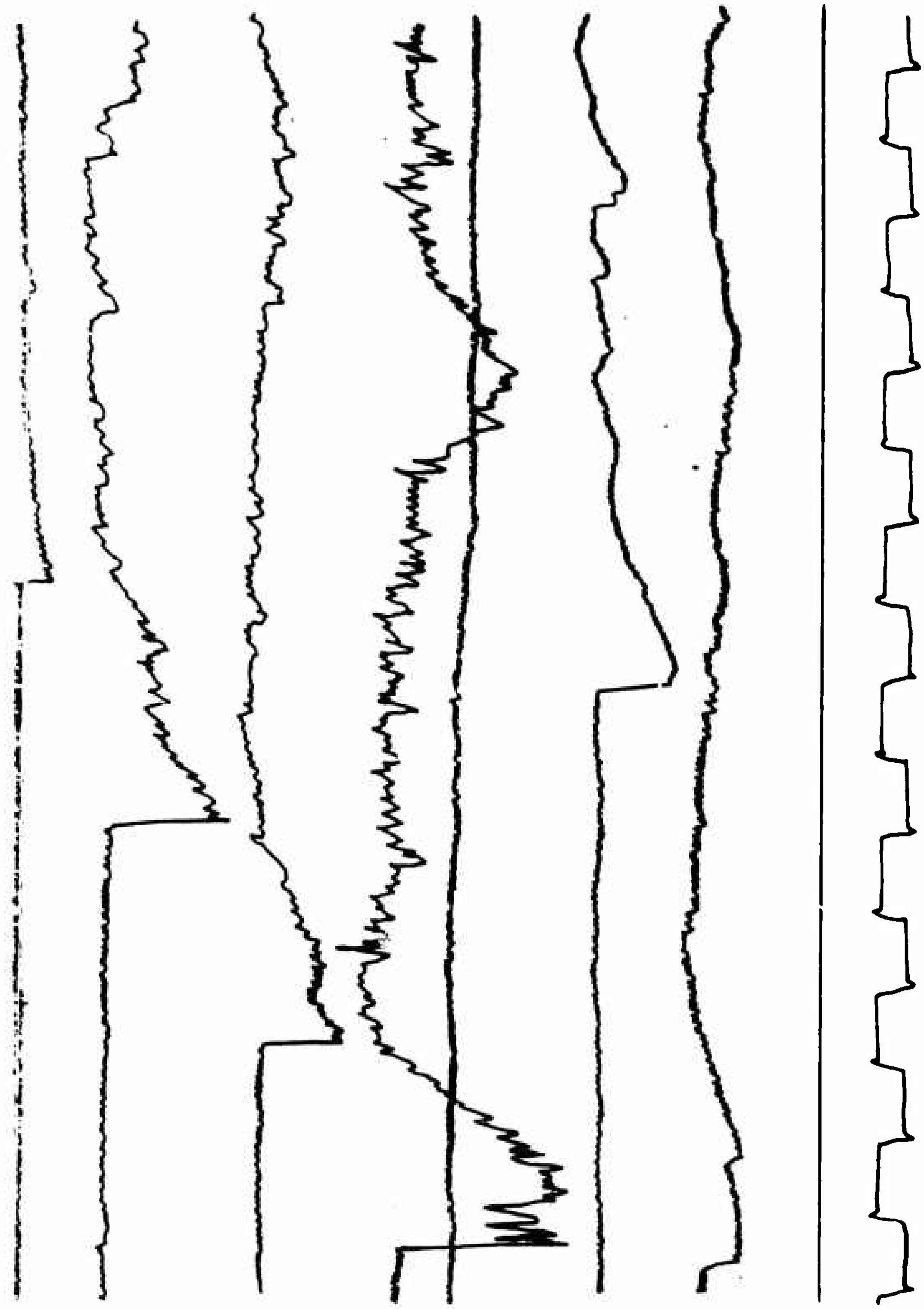


Fig. 6 - Strip Chart Data for Typical 105 mm SEAS Round
(Round 46, 11 June 1973)

most data traces.) The second method of reducing the data was to fair the data traces from a couple of milliseconds downstream of the initial spike, back to the initial spike. This method results in the reduced pressures being higher than Picatinny's for some cases and lower for others. A typical example of how this was accomplished is shown in Fig. 7. By fairing the data there seems to be less scatter in the results obtained for similar firings.

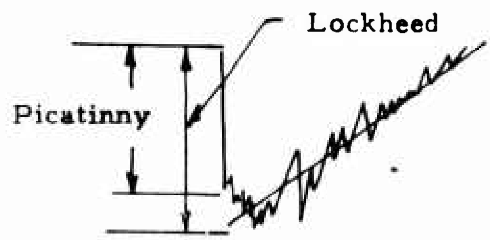


Fig. 7 - Data Reduction Scheme

2.5 TESTS PERFORMED WITH LOCKHEED DEVICES

The purpose behind firing the 105 mm recoilless rifle test weapon with the Lockheed pressure suppression devices was to evaluate the effectiveness of these devices in reducing the blast overpressure which an Army helicopter would experience. The tests which were made with the shroud and the deflector device are listed in Table 1. This table gives not only the test configuration but also the data which were obtained. The shroud tests were made so that it was possible to determine the amount of suppression obtained as a function of shroud porosity and length. The only variable which was obtained from the deflector device was the effect of placing the device parallel or perpendicular to the pallet surface. The results of these tests are presented and discussed in the next section.

2.6 RESULTS

The results of the 105 mm firings which were made from February through July 1973 are presented in this section. Local peak reflected overpressures at

Table 1

SUMMARY OF FIRINGS OF 105 MM TEST WEAPON WITH LOCKHEED SHROUD/DEFLECTORS ATTACHED

Round	Date (1973)	Chamber Press (psia)	Description
14	2-27	7789	Shroud at 25% Porosity (data at 12, 24, 48, 83, 179 in.)
22	3-7	7064	Shroud at 35% Porosity (data at 12, 24, 48, 83, 179 in.)
23	3-7	7092	Shroud at 10% Porosity (data at 12, 24, 48, 83, 179 in.)
34	6-8	6581	Shroud at 10% Porosity (data at 48, 83, 115, 147, 179 in.)
35	6-8	6579	Shroud at 0 Porosity (hang fire) (data at 115, 147, 179 in.)
42	6-8	7054	Shroud at 35% Porosity (data at 115, 147, 179 in.)
45	6-11	4718	Shroud Extended 20 ft at 35% Porosity (data at 83, 115, 147, 179 in.)
55	7-19	4092	Flat Plates Perpendicular to Pallet (data at 115, 147 in.)
56	7-19	4421	Flat Plates Parallel to Pallet (data at 115, 147 in.)

Table 2

REFLECTED PRESSURES MEASURED ON PALLET FOR 105 MM SEAS TEST SERIES

Round No.	Description	Average Maximum Chamber Pressure (psia)	Reflected Pressures (psi) Measured along Pallet Centerline Referenced to Exit Plane of Nozzle							Sym.
			12 in.	24 in.	48 in.	83 in.	115 in.	147 in.	179 in.	
11	105 mm	2843	1.43	2.05	2.5	3.09			2.15	
12	105 mm	6115	2.3	4.86	9.78	7.18			15.6	
14	105 mm Shroud at 25% Porosity	7789	1.65	2.22	2.84	11.1			37.2	
15	105 mm	3135	2.52	3.42	4.2	8.31			15.6	
16	105 mm	8326	2.0	2.88	2.29	12.98			24.	
17	105 mm	4844	2.37	3.22	4.43	8.79			16.6	
19	105 mm	6596	1.8	2.8	6.1	14.3			14.9	
22	105 mm Shroud at 35% Porosity	7064	1.9	2.8	3.7	9.7			39.5	
23	105 mm Shroud at 10% Porosity	7092	0.2	1.3	1.7	6.3			33.8	
30	105 mm	4353			5.51	8.98	9.59	11.39	2.29	
31	105 mm	4028			5.04	6.48	10.6	12.4		
32	105 mm	4775					9.6	15.7	3.6	
33	105 mm	6185			5.83	10.31	16.3	16.5	3.3	
34	105 mm Shroud at 10% Porosity	6581				11.08	15.0	21.7	5.09	
35	105 mm Shroud at 0% Porosity	7078					5.2	12.3	3.09	
42	105 mm Shroud at 35% Porosity	7104					16.6	13.5	4.91	
43	105 mm	6145				10.9	15.0	17.0		
44	105 mm	6276			16.3		12.0	8.5		
45	105 mm Shroud at 35% Ext. 20 in.	4718				2.84	4.0	4.74	2.54	
46	105 mm	4492				8.0	10.8	9.93	3.64	
48	105 mm	4703			3.15		16.15	12.46	2.73	
49	105 mm	5495			3.46		20.0	12.17	4.91	
50	105 mm	5379			6.3		25.	18.12	3.27	
51	105 mm	4802					10.6	12.7		
52	105 mm	6292					20.4	17.8		
53	105 mm	7706					22.3	17.4		
54	105 mm	8527					33.3	18.4		
55	105 mm **Flat Plate** Deflectors Vert.	4092					11.	7.45		
56	105 mm Flat Plate Deflectors Horiz.	4421					9.6	7.6		
57	105 mm	3971					11.3	12.2		
58	105 mm	3996					13.0	10.2		

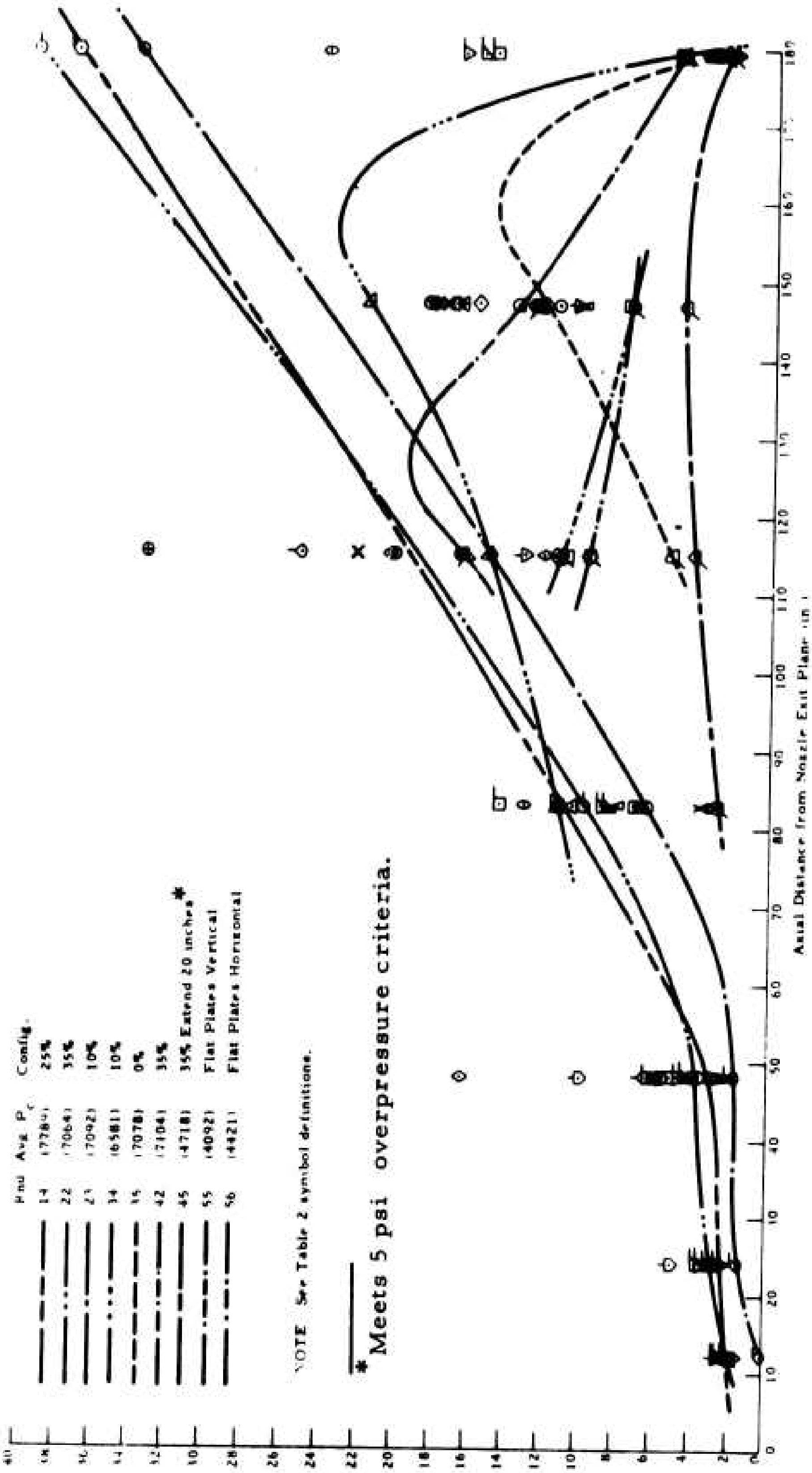


Fig. 8 - Lockheed Reduced Initial Peak Reflected Pressure Data Measured on Pallet for Seas 105 mm Blast Attenuation Rounds 11-58

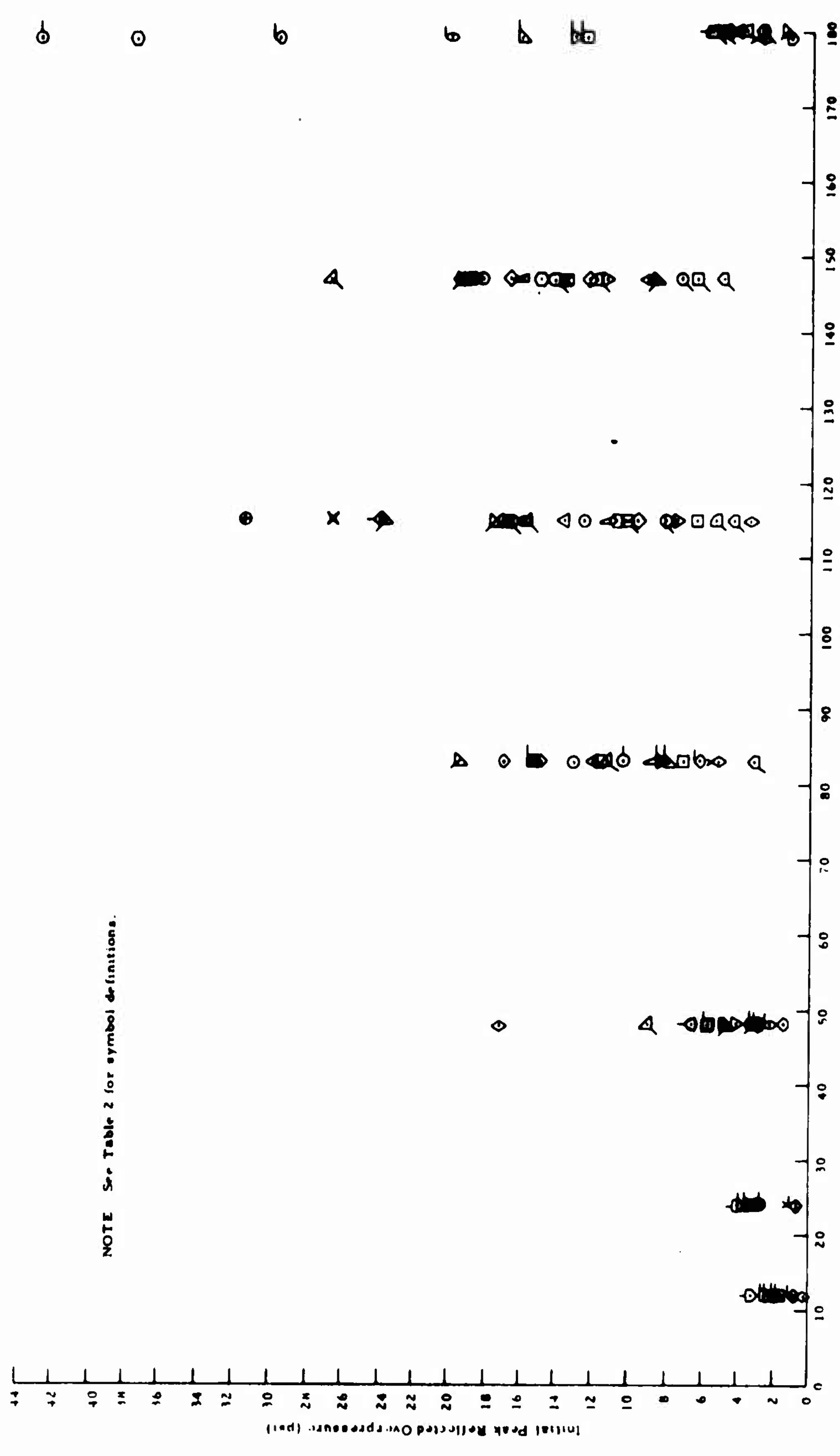


Fig. 9 - Picatinny Reduced Initial Peak Reflected Pressure Data Measured on Pallet for Seas 105 mm Blast Attenuation Rounds 11-58

various locations on the instrumented pallet comprise the bulk of the data. A summary of all that reflected pressure data used in this section is presented in Table 2. This table represents the peak overpressures as reduced by Lockheed (Section 2.4). Figure 8 presents the overpressure data from Table 2 plotted as a function of axial distance along the centerline of the pallet measured from the breech nozzle exit plane of the rifle. Figure 9 presents the same set of data as reduced by Picatinny Arsenal (see Section 2.4). Curves are faired through the results of the rounds fired with the shroud and the deflectors. Note that the data presented in Figs. 8 and 9 are the result of two series of tests. The first series produced data which are significantly higher in the far-field range of 100 to 179 inches than were obtained in the second series of tests. This trend persists for both the shrouded and unshrouded rounds. This trend might possibly be caused by the "ringing" effect on the transducers due to vibrations set up in the first set of firings in the single aluminum strip in which the transducers were mounted. Therefore, most of the far-field observations which are made in the results will be made based on the second series of firings.

There was also a wide variety of the M8 propellant lots, web thickness, strip size and strip numbers for the two series of tests. Andrade in Ref. 2 presents some results of free-field data indicating that the blast waves and field can be attenuated and altered by the propellant loading and burning characteristics as well as fluid mechanical techniques such as the shroud. No comparisons of the data in this report are made based on the propellant characteristics.

Figure 8 essentially presents the results of all the 105 mm tests (using the pallet instrumentation) made between February and July of 1973. Although the figure is a little cluttered with data it is useful because definite trends become apparent. The data obtained from firings involving the shroud and deflector device indicate that significant attenuations in the blast flow fields were obtained by using these devices. The only configuration which met the requirement of a 5 psi maximum overpressure was round 45 which was fired with the shroud set at 35% porosity and extended 68 inches from the nozzle exit plane. The other rounds fired with the shroud set at 35% porosity significantly

2. Andrade, C. A., "Memo for Record-SEAS 105 mm RR Blast Wave Attenuation," SWEWV-RDD-SE, Watervliet Arsenal, Watervliet, N. Y., 1 May 1973.

shifted the location of peak pressure on the pallet and reduced the overpressures out to 83 inches but their peak pressures as well as the non-shrouded overpressures were approximately as high as eight times those produced by round 45 at station 179 versus rounds 22 and 42 of comparable P_{max} and geometry. This seems to indicate a strong dependence on shroud length-to-inner-diameter ratio, at least for the 35% porosity setting.

The zero porosity round seems to significantly reduce the pressures (below 5 psi) out to 130 to 140 inches and beyond this range the results are similar to the unshrouded rounds (5 to 15 psi). Two rounds were fired at 10% porosity (23 and 34). Round 23 shows the minimum pressures of the data taken out to 83 inches at which point the results became higher than the unshrouded data. Round 34 showed higher pressures at 83 inches than round 23 then the pressures dropped below that of round 23 beyond 115 inches but still above all the unshrouded data. Round 14 was fired at 25% porosity and exhibited a pressure versus axial distance distribution very close to round 22 which was fired at a 35% porosity.

The two firings which were made with the flat plate deflectors were rounds 55 and 56. Round 55 was fired with the plates vertical to the pallet and round 56 was fired with the plates parallel to the pallet. The only data obtained from these firings were at 115 and 147 inches. At 115 inches the horizontal flat plate round resulted in the lowest overpressure of all the data taken except for the zero porosity shroud and the 35% extended shroud. The vertical round had an overpressure which was 1.5 psi higher than the horizontal round but still in the lower part of data scatter. At 147 inches both rounds produced the lowest overpressures (7.3) of all rounds fired except for the 35% extended round (45).

Figures 10 through 16 represent the data for all rounds plotted against peak average chamber pressure at Stations 12, 24, 48, 83, 115, 147 and 179 inches, respectively. Figure 10 for $x = 12$ indicates that the peak overpressures at this station is fairly constant at about 2.0 psi although the 10% shroud data

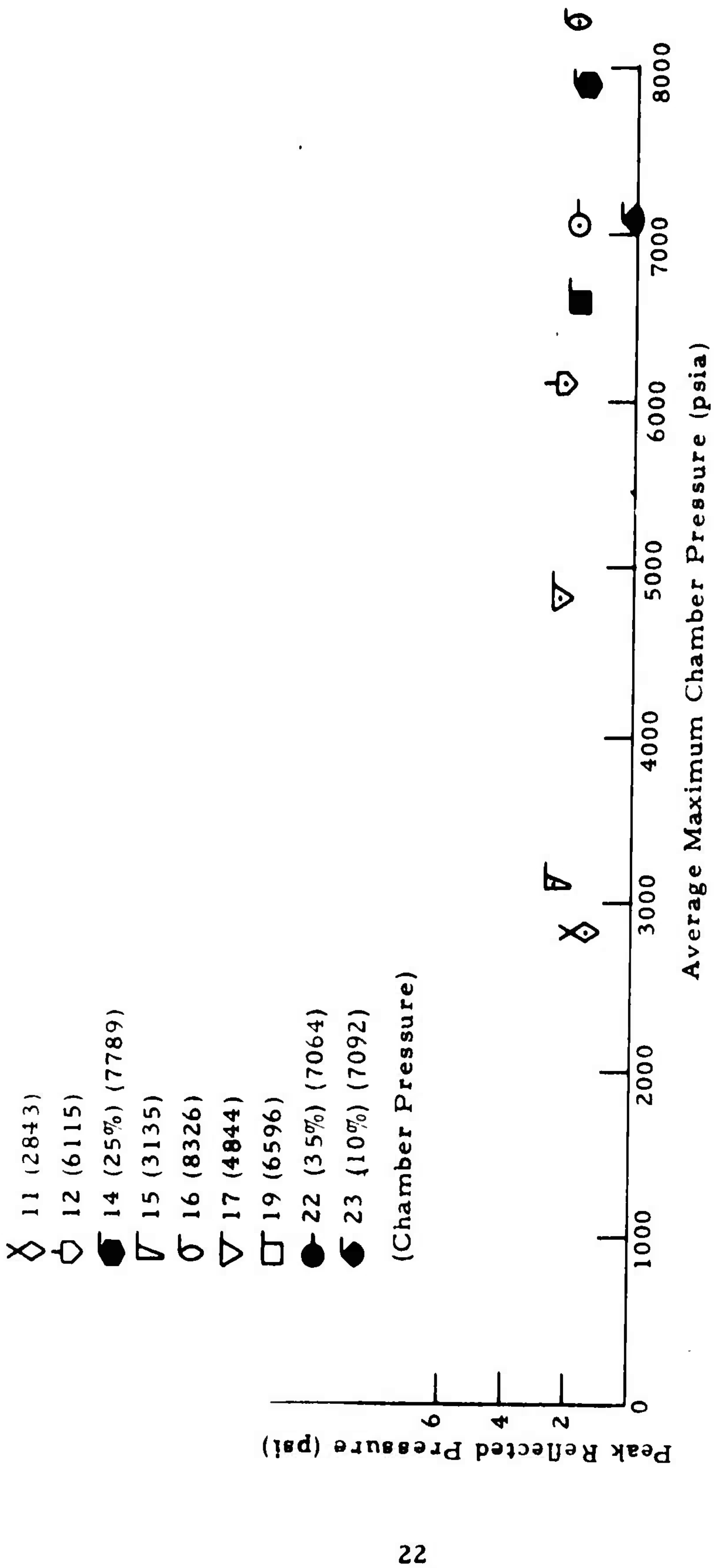


Fig. 10 - Peak Reflected Overpressure vs Average Maximum Chamber Pressure for x = 12 in. on Reflection Plane

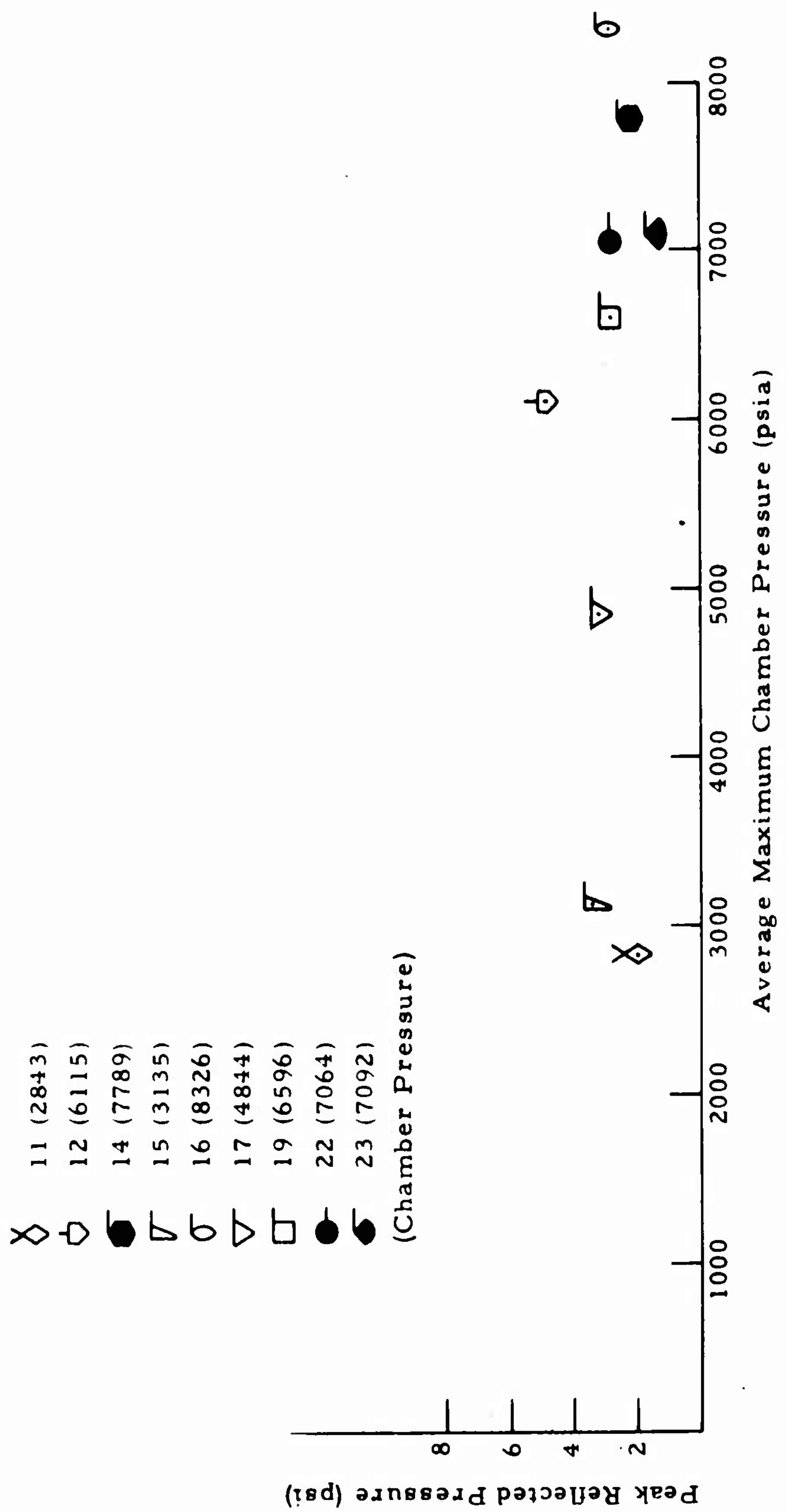


Fig. 11 - Peak Reflected Overpressure vs Average Maximum Chamber Pressure for x = 24 in. on Reflection Plane

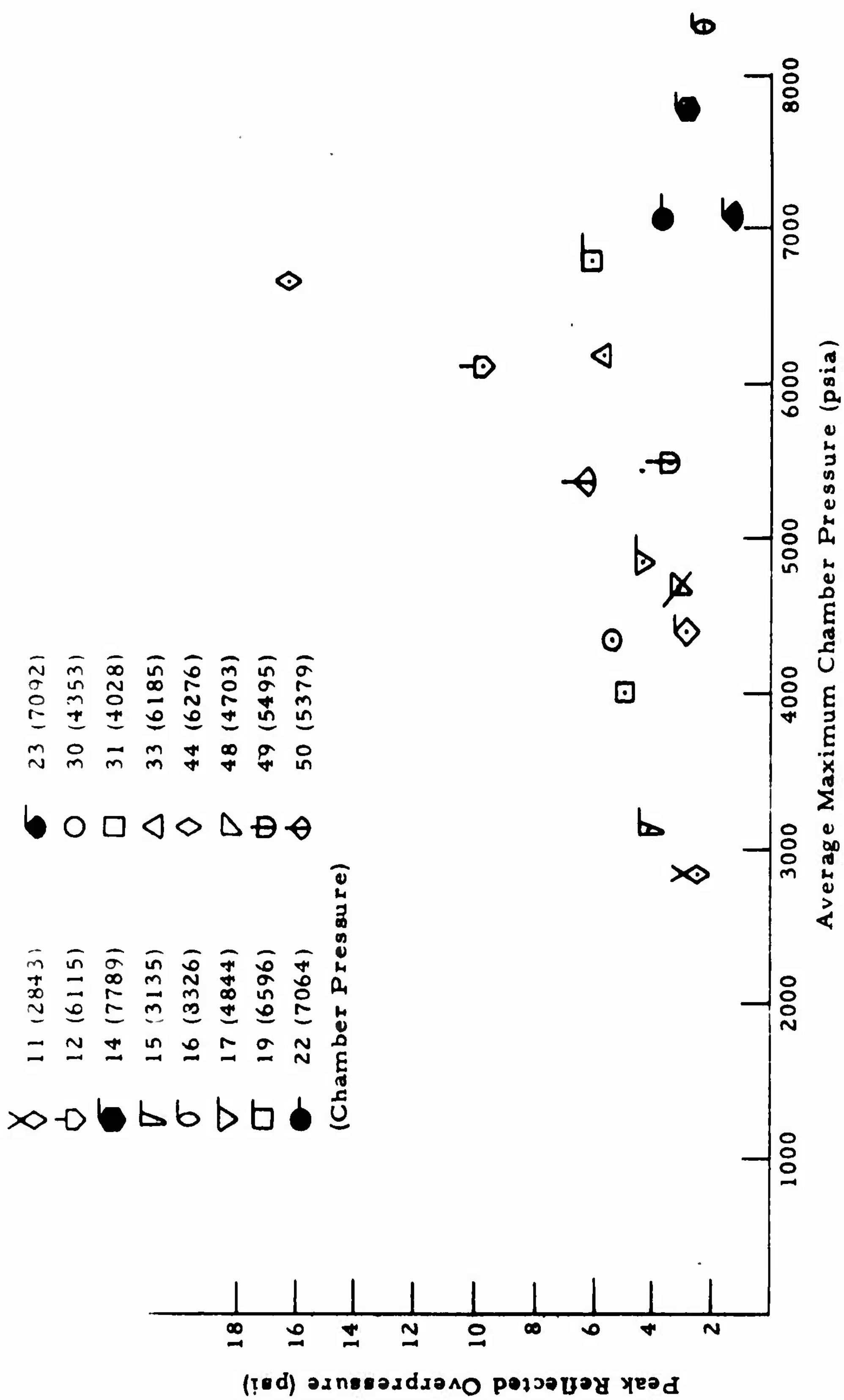


Fig. 12 - Peak Reflected Overpressure vs Average Maximum Chamber Pressure for x = 48 in. on Reflection Plane

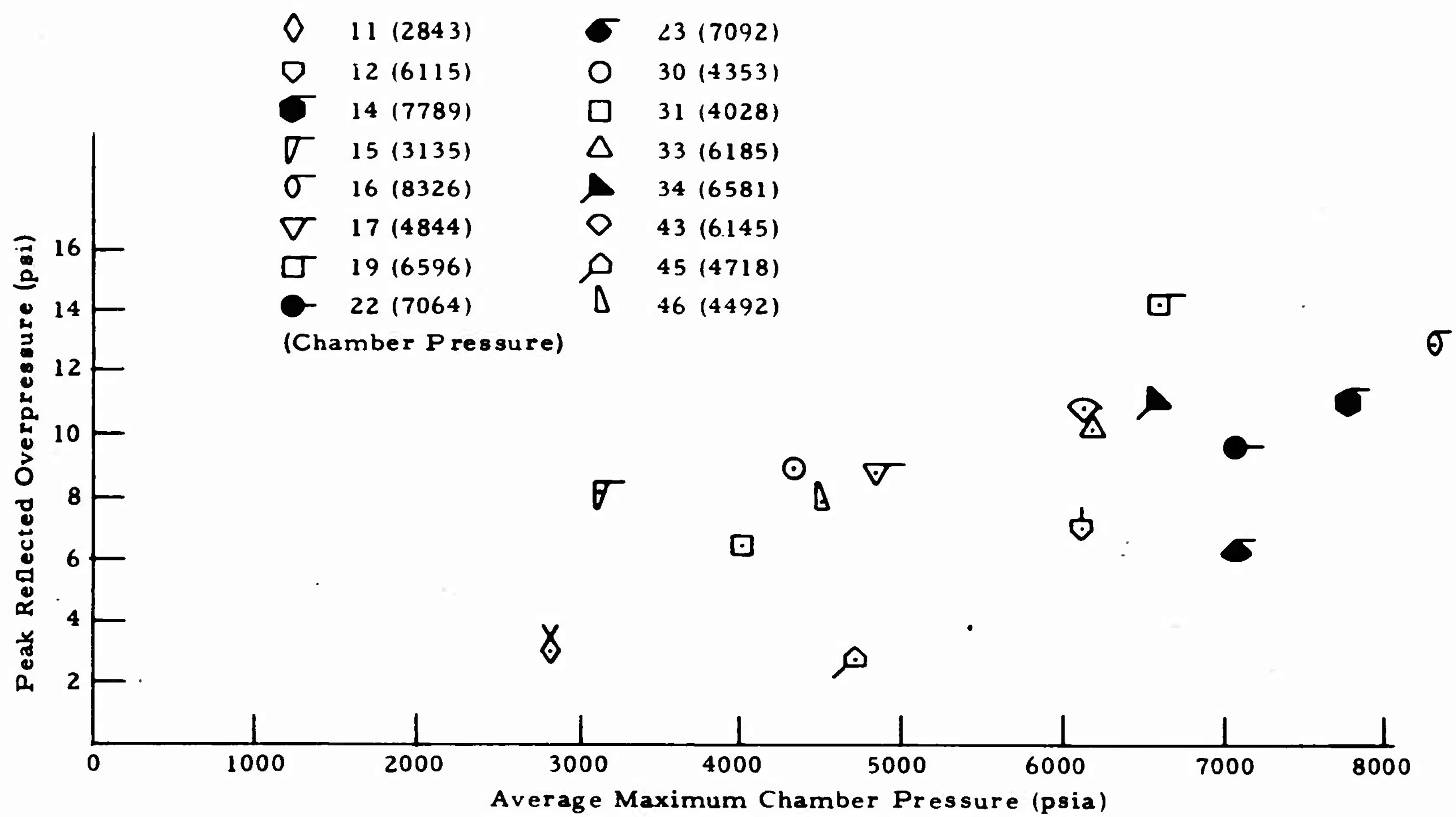


Fig. 13 - Peak Reflected Overpressure vs Average Maximum Chamber Pressure for x = 83 in. on Reflection Plane

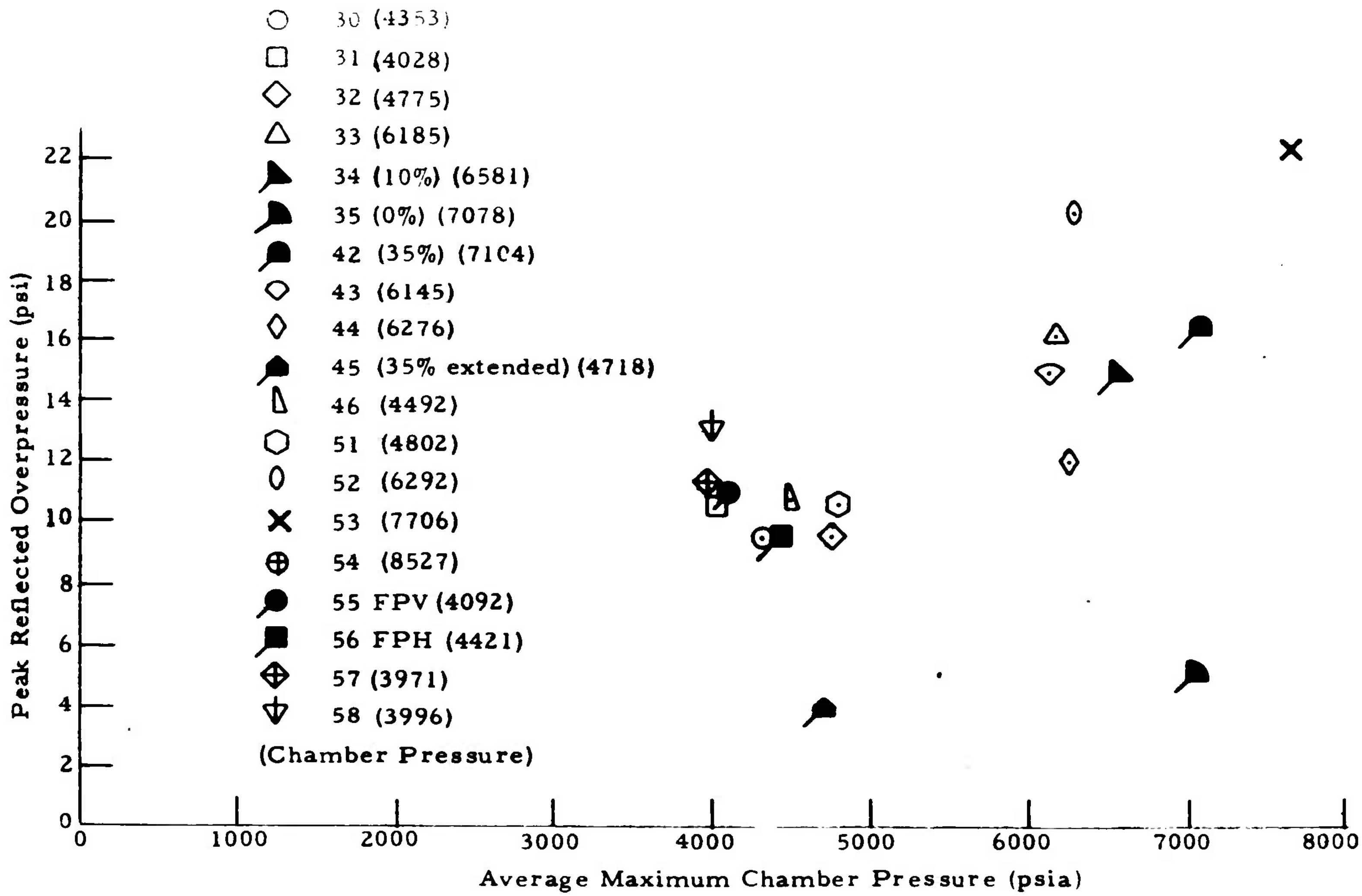


Fig. 14 - Peak Reflected Overpressure vs Average Maximum Chamber Pressure for x = 115 in. on Reflection Plane

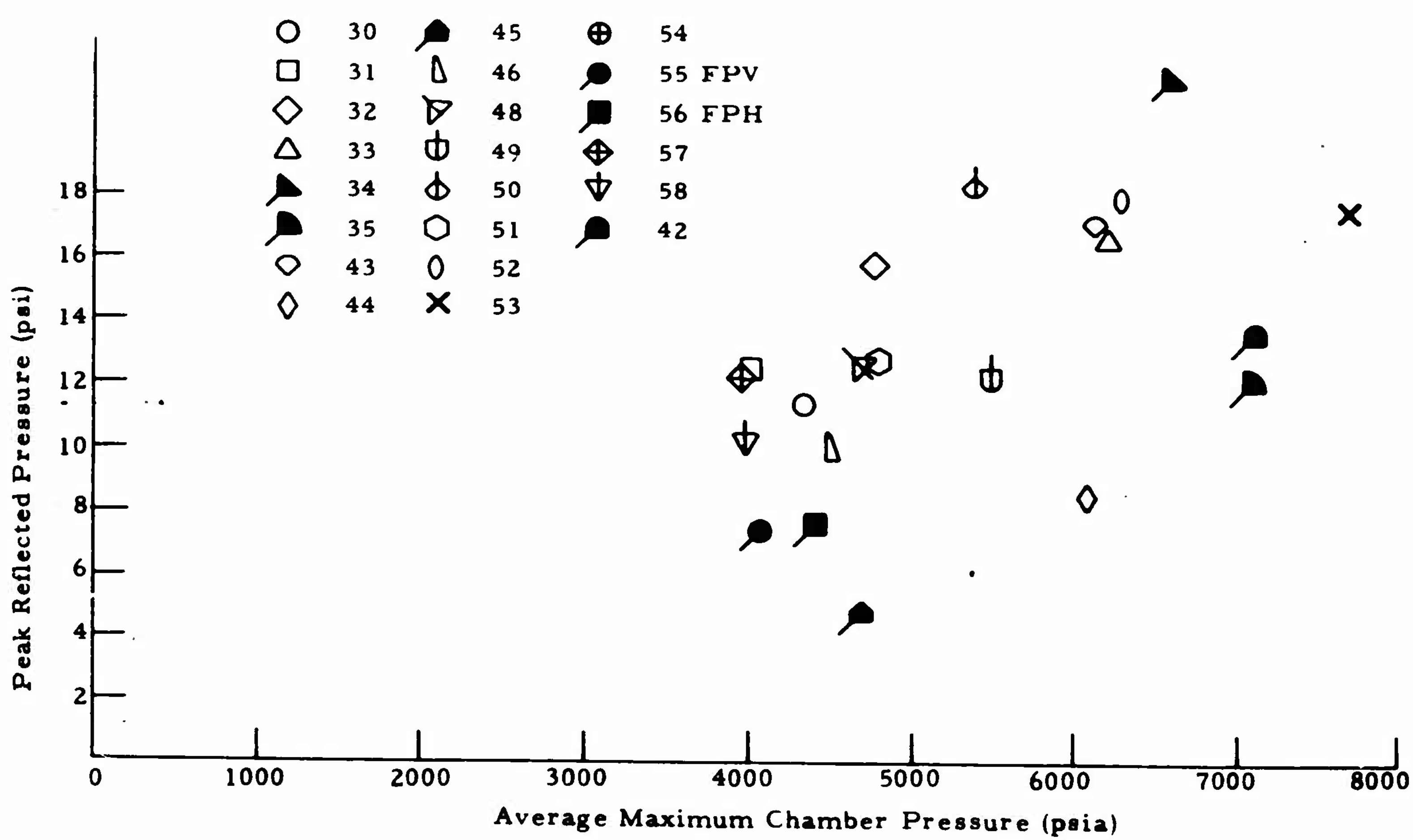


Fig. 15 - Peak Reflected Overpressure vs Average Maximum Chamber Pressure for x = 147 in. on Reflection Plane

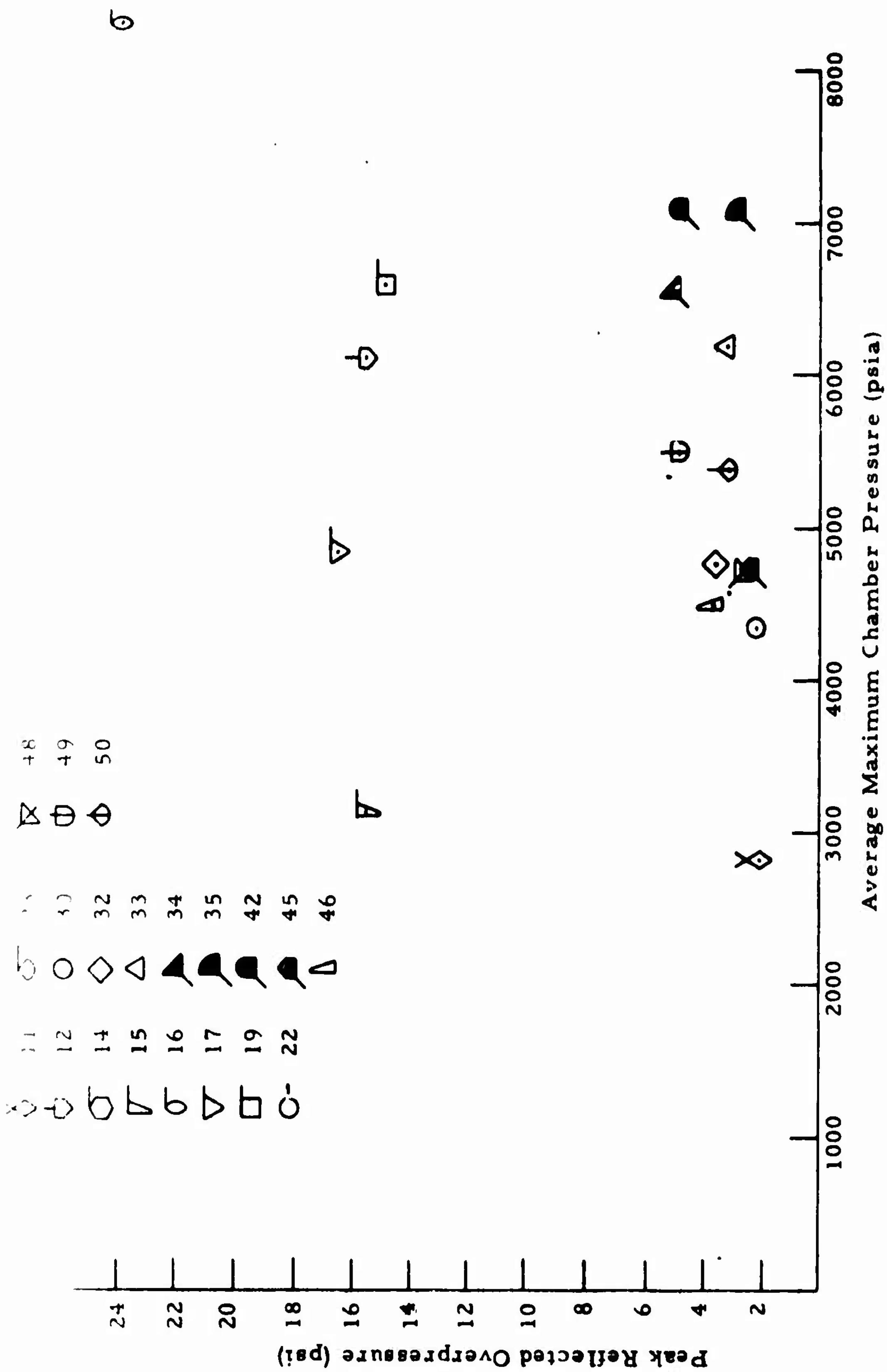


Fig. 16 - Peak Reflected Overpressure vs Average Maximum Chamber Pressure for x = 179 in. on Reflection Plane

point is only about 0.1 psi. Figure 11 for x = 24 inches again shows the overpressure (3 psi) as being fairly constant with chamber pressure with the 10% shroud round being at 1.25 psi. Figure 12 for x = 48 inches shows an upward trend in overpressure except for the shrouded rounds which at 7000 to 7800 psia average chamber pressure the 10, 25, and 35% porosity rounds are lower. Figures 13, 14 and 15 for x = 83, 115 and 147 show the same trends of overpressure dependence on chamber pressure although there is a fairly wide scattering in the data which might be caused by variations in propellant loading characteristics as indicated by Andrade (Ref. 2). The data points for rounds 0, 25 and 35% porosity rounds are on the low overpressure side of the data scattering and the 10% rounds are on the middle and high side of the data. Figure 16 for x = 180 inches shows very little overpressure dependence on chamber pressure except for the rounds fired in the first series of tests which may be questionable due to vibration effects.

Figures 17 through 23 present peak reflected overpressure plotted versus shroud porosity for stations 12, 24, 48, 83, 115, 147, 179 inches, respectively. In Figs. 17, 18, and 19 for Station 12, 24 and 48 the minimum overpressure (0.0 to 1.0 psi) is obtained for a porosity below 10%. The peak in overpressure occurs somewhere beyond 35%. In Fig. 20 for x = 83 the standard length shroud porosity (L/D = 4.8) which produces the minimum overpressure may be found either below 10% or above 35% as there appears to be a peak around 25%. The dashed line through round 45 indicates what the overpressure porosity curve might look like for shroud L/D = 6.8. At x = 115 inches in Fig. 21 for L/D = 4.8 the minimum pressure (5.2 psi) was obtained at zero shroud porosity and the peak occurs around 30 to 35% porosity. Again the dashed line through round 45 (L/D = 6.8) indicates the possible trend with L/D variation. For x = 147, Fig. 22 shows that for an L/D = 4.8, the peak overpressure (22 psi) occurs about 20% porosity and rapidly falls off below and beyond this setting. For L/D = 6.8, the dashed line through round 45 shows L/D variation with porosity. At Station 179, Fig. 23 shows three families of curves. The first set exhibits high resulting overpressures (34 to 40 psi) with a trend of increasing overpressure with increased porosity for L/D = 4.8. This curve was the data from the first series of firings and round 34. The second curve for rounds 23, 35, 42, (L/D = 4.8) peaks at 5.5 psi at 25% porosity. The dashed line through round 45 (L/D = 6.8) shows L/D variations and peak overpressures of about 3.5 psi.

2. Andrade, C. A., "Memo for Record-SEAS 105 mm RR Blast Wave Attenuation," SWEWV-RDD-SE, Watervliet Arsenal, Watervliet, N. Y., 1 May 1973.

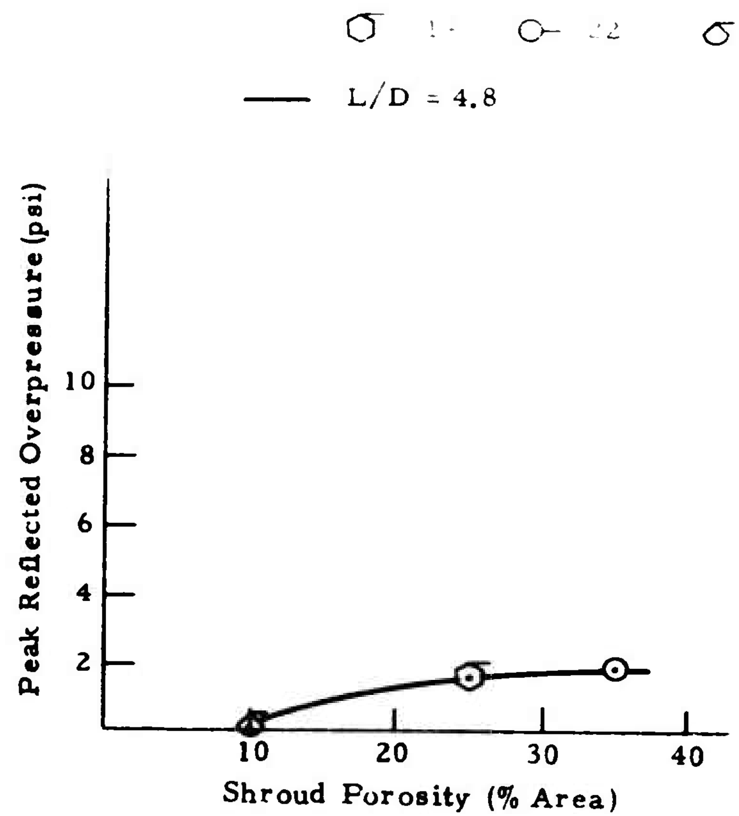


Fig. 17 - Initial Peak Reflected Pressure vs Shroud Porosity Measured on Reflection Plane at x = 12 inches

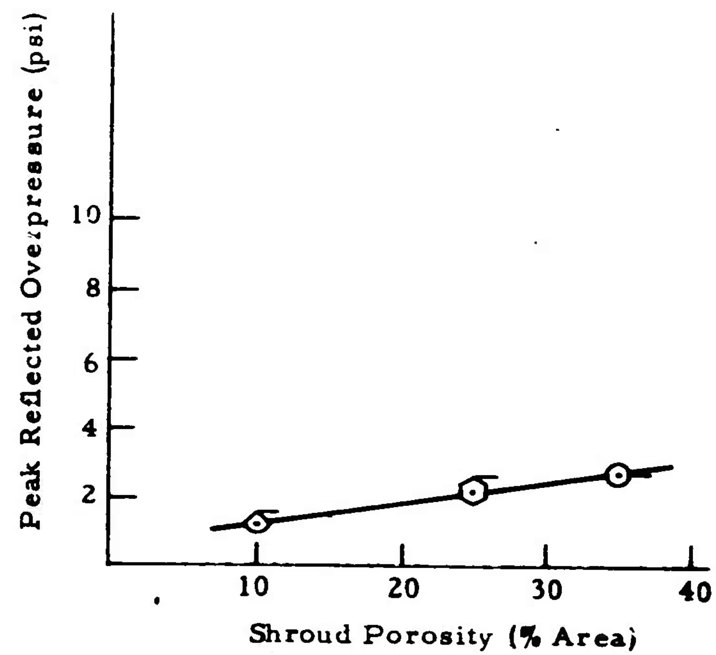


Fig. 18 - Initial Peak Reflected Pressure vs Shroud Porosity Measured on Reflection Plane at x = 24 inches

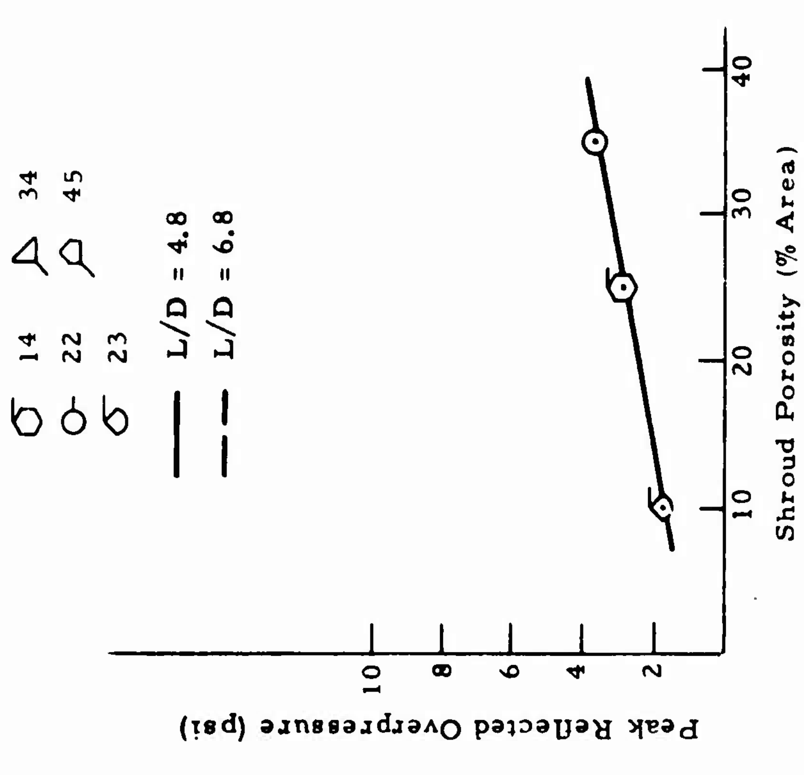


Fig. 19 - Initial Peak Reflected Pressure vs Shroud Porosity Measured on Reflection Plane at x = 48 inches

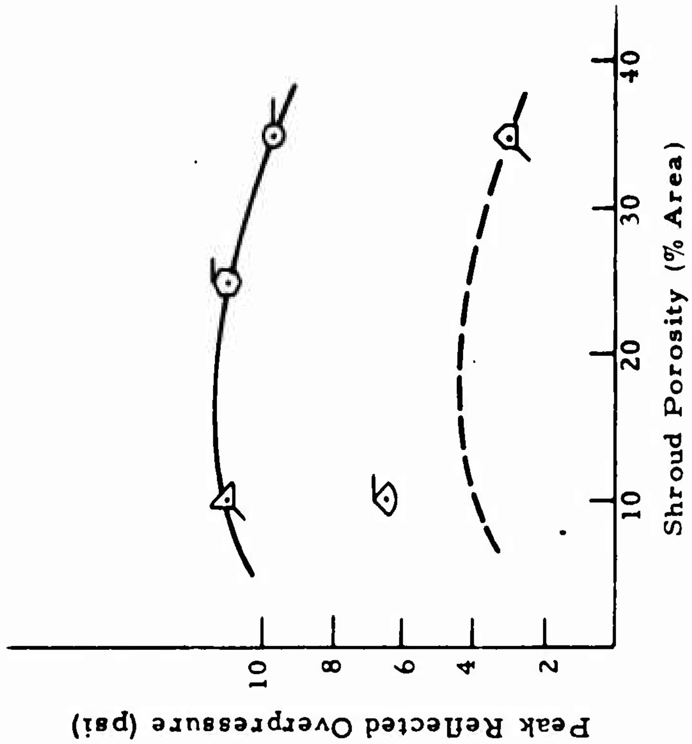


Fig. 20 - Initial Peak Reflected Pressure vs Shroud Porosity Measured on Reflection Plane at x = 83 inches

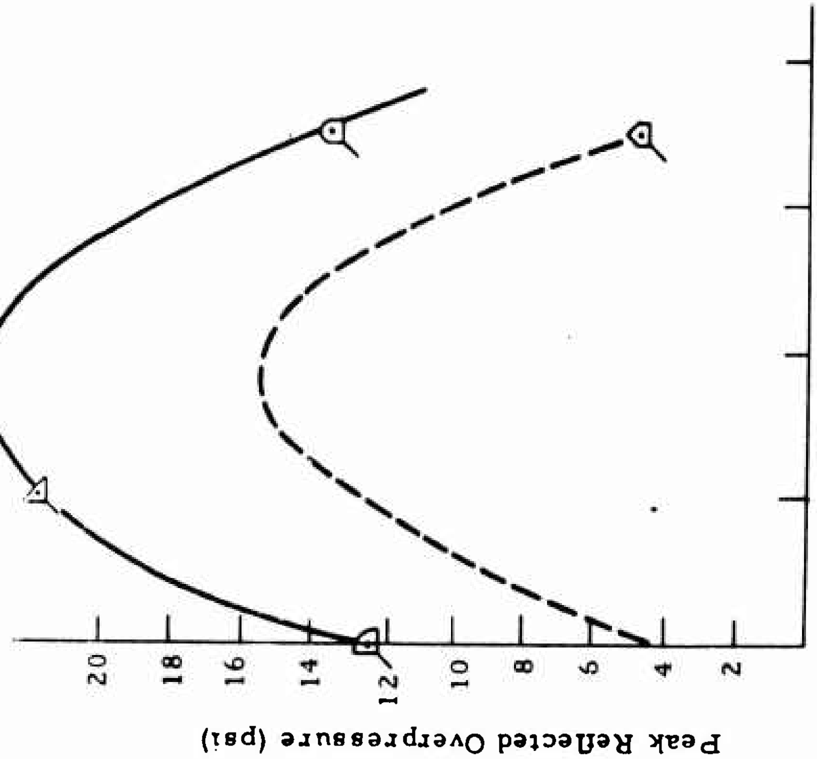


Fig. 22 - Initial Peak Reflected Pressure vs Shroud Porosity Measured on Reflection Plane at x = 147 inches

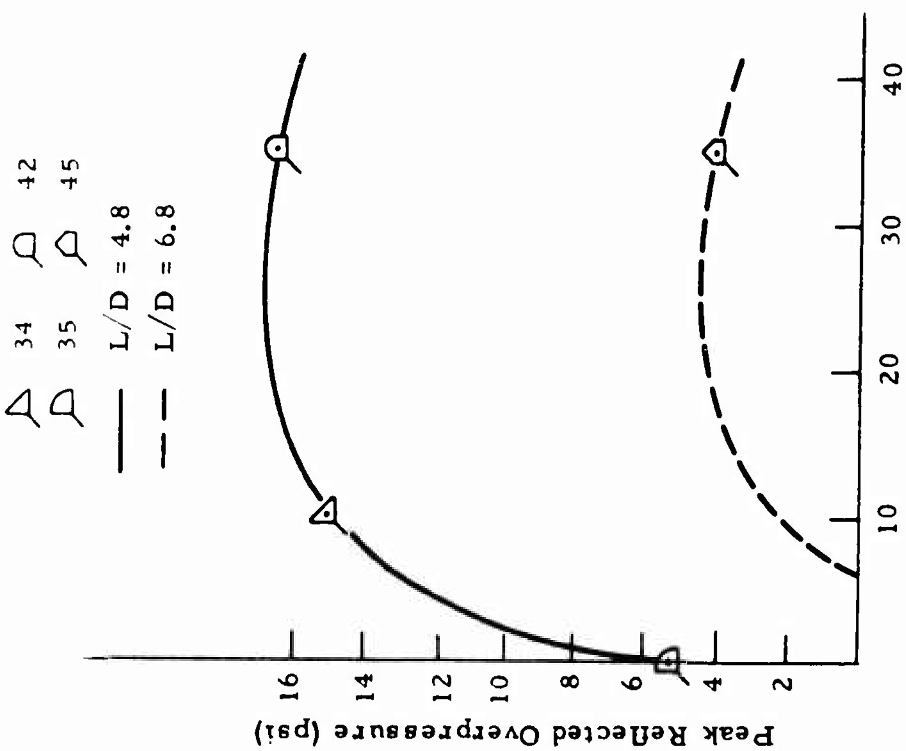


Fig. 21 - Initial Peak Reflected Pressure vs Shroud Porosity Measured on Reflection Plane at x = 115 inches

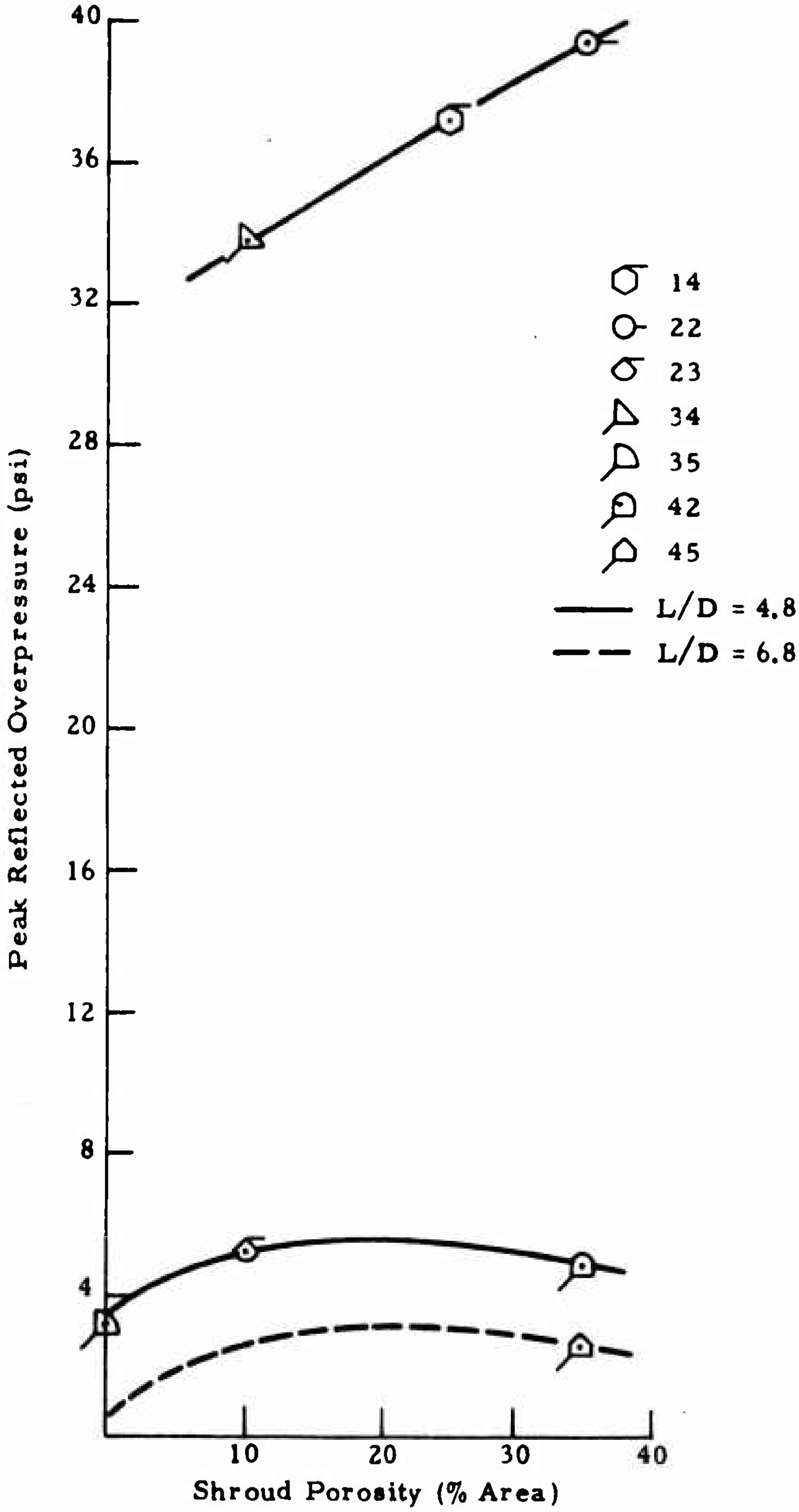


Fig. 23 - Initial Peak Reflected Pressure vs Shroud Porosity Measured on Reflection Plane at x = 179 inches

Section 3
CONCLUSIONS

The design, fabrication and testing of the back blast attenuation devices were accomplished. Round 45 (L/D = 6.8, 35% porous shroud) attenuated the measured overpressure field to levels near 5 psig. The results of round 45 and the trends of other shrouded rounds demonstrated that it is feasible to use a shroud to permit operation of a recoilless rifle on an Army helicopter. The weapon system length constraint as well as the 5 psi overpressure constraint can probably be met by reducing the inner diameter of the shroud L/D near 7.0. This will result in a significantly shorter and lighter shroud which can be tailored for operational applications.

During the second series of 105 mm recoilless rifle firings there were three unshrouded rounds (46, 48, 51) fired which had maximum chamber pressures in the same 4500 to 4700 psi range as round 45. The average reduction in measured reflected pressures ranged from a factor of 2.8 at 83 and 115 in., 2.5 at 147 in. to a factor of 1.5 at 179 in. The overpressures measured for round 45 ranged from 2.54 to 4.74 psig as shown in Table 2.

All the tasks which were undertaken under this contract have been performed successfully. A round was fired with the shroud set at 35% porosity and an L/D = 6.8 which resulted in peak reflected overpressures on a simulated helicopter side panel which did not go above 5 psi. A device may be obtained which both meets the overpressure requirement and the overall weapon length constraint by reducing the shroud diameter to the nozzle exit diameter and maintaining an L/D = 6.8. It is possible that by varying porosity and by going to a double shroud the peak reflected overpressures may be further reduced and thereby allow higher chamber pressure rounds which result in higher projectile muzzle velocity. By going to a thin wall stainless steel or filament wound shroud a fairly light weight and recoilless back blast attenuator will

result which may be highly feasible for mounting on a 105 mm/Cobra helicopter system.

It is recommended that additional firings be made with a smaller diameter shroud which meets the weapon length constraint. The test should be made varying porosity and also investigate the use of a double shroud. These tests should be performed using the optimum propellant loading combination which results in the most attenuated non-shrouded blast flow field. Numerous tests should be made for each desired setting so good data repeatability may be determined.

A dominant controlling process in blast wave attenuation has been determined experimentally and the experimental trends have been qualitatively verified analytically (Vol. II). Ultimate recoilless operation with a shroud can be obtained and optimized through tailoring the shroud and breech nozzle using such techniques as a diverging shroud, angled porous shroud holes or nozzle design. Specific applications would involve tailoring a rifle system by combining chamber pressure time history, grain design and diffuser design to obtain a particular weapon system performance.

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